6. Radiation and Foreign Research Reactor Spent Fuel

6.1 What is radiation?

All matter is composed of elements, and each element can take many different forms, called isotopes. The difference between isotopes of the same element is in their number of neutrons. Some isotopes are unstable and emit radiation, which is energy given off by atoms when they move or change state. These unstable isotopes are known as radionuclides. Stable isotopes do not emit radiation.

6.2 What is ionizing radiation?

Ionizing radiation refers to any type of radiation that can change the electric charge of atoms or molecules. Radionuclides in nuclear waste, including spent fuel, produce ionizing radiation. Ionizing radiation comes in particle forms, such as alpha and beta particles, and nonparticle forms, such as x-rays and gamma radiation.

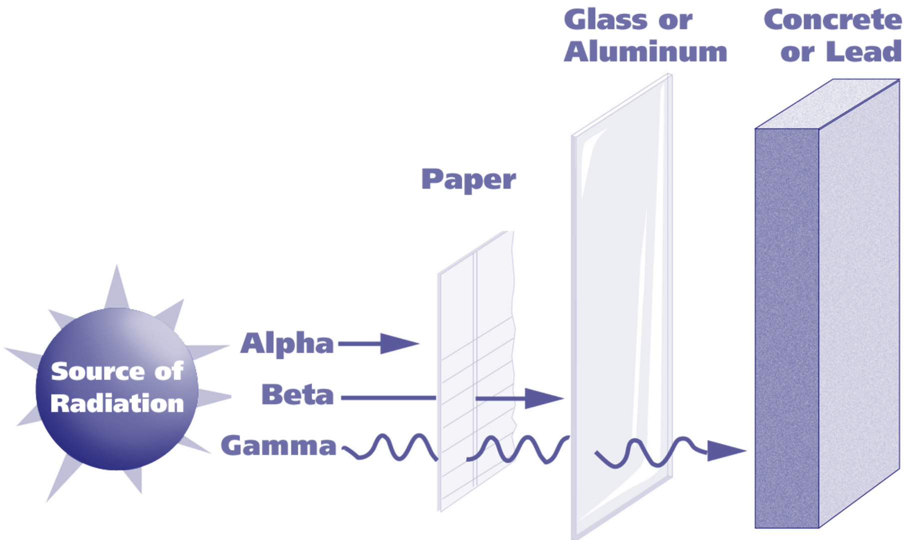
6.3 Which types of ionizing radiation does spent nuclear fuel emit?

Spent fuel emits three types of ionizing radiation—alpha particles, beta particles, and gamma rays.

- **Alpha particles** can travel only a few inches in the air and lose their energy almost as soon as they collide with anything. A sheet of paper or the outer layer of a person's skin can easily stop alpha particles.

- **Beta particles** move faster and are much lighter than alpha particles. They can travel in the air for a distance of a few feet. Beta particles can pass through a sheet of paper but can be stopped by a sheet of aluminum or glass.

- **Gamma rays** are waves of pure energy and are similar to x-rays. They travel at the speed of light through air or open spaces. Concrete, lead, or steel is commonly used to block gamma rays.



6.4 What are typical units of measurement for radiation and radioactive materials?

Measurements used in the United States include the following:

- **Curie** is a unit of radioactivity. One curie refers to the amount of any radionuclide that undergoes 37 billion atomic transformations a second.

- **Roentgen** is a measure of exposure. It describes the amount of radiation energy, in the form of gamma or x-rays, in the air.

- **Rad** (radiation absorbed dose) measures the amount of energy actually absorbed by a material, such as human tissue.

- **Rem** (roentgen equivalent man) measures the biological damage of radiation. It takes into account both the amount, or dose, of radiation and the biological effect of the type of radiation in question. A **millirem** is one one-thousandth of a rem.

6.5 What are common sources of human exposure to radiation?

Although individual exposures vary, humans are routinely exposed to radiation from natural sources, such as indoor radon and cosmic rays from outer space, and from manufactured sources, such as medical x-rays and televisions. People are also exposed to radiation from naturally occurring radioactive elements in the human body, such as potassium. Because individual human exposures to radiation are usually small, the millirem (one one-thousandth of a rem) is generally used to express doses humans receive.

The average person in the United States is exposed to an estimated 300 millirem of radiation from natural sources (known as background radiation), such as cosmic rays and household radon, and to an additional 60 millirem from other sources, such as medical x-rays or treatments, each year. The total average annual exposure for an individual in the United States is about 360 millirem. The following table shows average radiation doses from several common sources of human exposure.

Common Radiation Sources and Estimated Doses

Radiation Source	Estimated Dose (millirem)
Chest x-ray	8
Cosmic rays (U.S. average)	27 (annually)
Household radon	200 (annually)
Naturally occurring elements in human body (e.g., potassium)	39 (annually)
Round-trip cross-country airline flight	5

6.6 What harmful effects can ionizing radiation have on human health?

Ionizing radiation is powerful enough to alter cellular chemicals and disrupt normal cell functioning. All three types of ionizing radiation can be harmful to humans. Gamma rays from sources outside the body can penetrate and cause damage throughout the human body. Inhaling or ingesting substances that emit gamma rays is also potentially harmful. Alpha and beta particles can cause damage to human tissue primarily through inhalation or ingestion.

Two types of cellular damage can result from exposure to ionizing radiation:

- **Genetic damage,** which alters—or mutates—reproductive cells, causes damage to future generations.

- **Somatic damage,** which alters ordinary, nonreproductive cells, harms the exposed individual in his or her lifetime but is not passed on to offspring. Cancer, including some leukemias and bone, thyroid, breast, skin, and lung cancer, is the dominant type of somatic damage resulting from exposure to ionizing radiation. Other types of somatic damage include burns and cataracts.

The nature and extent of damage from ionizing radiation depend on a number of factors, including the amount of exposure, the frequency of exposure, and the penetrating power of the radiation to which a person is exposed. Exposure to very large doses of ionizing radiation within a short period of time is rare but can cause death within a few days or months. The sensitivity of the exposed cells also influences the extent of damage. For example, rapidly growing tissues, such as developing embryos, are particularly vulnerable to harm from ionizing radiation.

6.7 How long does foreign research reactor spent fuel remain radioactive?

Foreign research reactor spent fuel remains radioactive virtually forever because it contains naturally occurring uranium-238, which has a half-life of 4.5 billion years. Most of the activity in spent fuel, however, comes from a mixture of fission products (e.g., cesium and strontium), and these eventually decay to levels that are essentially nonradioactive. The time it takes individual fission products to decay varies enormously—some take seconds, and others take years.

6.8 How much radiation do regulations allow a Type B spent fuel cask to emit?

NRC regulations set the maximum allowable radiation emission from a Type B spent fuel cask at 200 millirem per hour on the surface of a package and 10 millirem per hour at a distance of two meters (about 6.6 feet).

As of the end of May 1998, the highest radiation dose measured on the surface of a package of foreign research reactor spent fuel received at the Savannah River Site under the new program was 15 millirem per hour—significantly below the maximum allowable level.

6.9 What radiation dose would people receive who are exposed to a passing vehicle carrying casks of spent fuel?

If a train carrying eight casks of foreign research reactor spent fuel, with each cask emitting the *maximum* allowable amount of radiation (10 millirem per hour at two meters), stopped on the tracks for two weeks, a person standing 100 feet from the tracks *for the entire two weeks, without moving,* would receive a radiation dose approximately equal to the dose from one chest x-ray (8 millirem). An individual's background dose from natural radiation sources over the same two weeks would be approximately 14 millirem.

Exposure to a passing vehicle carrying a spent fuel shipment would result in an extremely small dose of radiation. For example, a person 100 feet from a foreign research reactor spent fuel transport vehicle moving 15 miles an hour would receive a radiation dose of less than one one-thousandth of a millirem.

A Guide to

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